Project ID: eems023

JUNE 1ST, 2020

U.S. DEPARTMENT OF ENERGY
SMARTMOBILITY
Systems and Modeling for Accelerated Research in Transportation

WHOLETRAVELER TRANSPORTATION BEHAVIOR STUDY

C. ANNA SPURLOCK
Research Scientist
Energy Analysis and Environmental Impacts Division
Lawrence Berkeley National Laboratory

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Argonne NATIONAL LABORATORY · BERKELEY LAB · INL Idaho National Laboratory · NREL · OAK RIDGE National Laboratory

OVERVIEW, RELEVANCE, MILESTONES & APPROACH

OVERVIEW

Timeline

- Start date: October 1, 2016
- End date: June 30, 2020
- Percent complete: 93%

Barriers

- Uncertainties associated with the energy impact of new mobility technologies arise primarily from lack of understanding of traveler behavior in the context of emerging technologies and services. Particularly:
  - Barriers and drivers of adoption and use
  - Heterogeneity in these barriers, drivers, adoption and use patterns that impact scope and timing of adoption/use

Budget

- Total project funding: $3.2M (all partner labs) –100% DOE
- Funding for FY 2017: $1.15M
- Funding for FY 2018: $1.125M
- Funding for FY 2019: $929K
- Funding for FY 2020: $100K

Partners

- Collaborators:
  - Berkeley Lab (project lead)
  - Idaho National Laboratory
  - National Renewable Energy Laboratory
  - Academic collaborators: UC Berkeley, Stanford University, Carnegie Mellon University, Youngstown State University
- Subcontractor
  - Resource Systems Group, INC (RSG)

RELEVANCE

- Provide vital insights to understanding the possible pathways to the vision of the EEMS Program:

“an affordable, efficient, safe, and accessible transportation future in which mobility is decoupled from energy consumption.”

- Conduct early-stage R&D at the traveler level to generate insights enabling a deeper understanding of the **individual behavioral and economic drivers of and barriers to increase mobility energy productivity** in the context of emerging and transformative transportation technologies and services.

MILESTONES

Milestone Name/Description	Criteria	End Date	Type	Status
Draft of LBNL report summarizing phase 1 data	Report submitted	12/31/2018	Quarterly	✓ SUBMITTED TO DOE AND UNDER REVIEW AT JOURNAL (entry 4 in the table on next slide)
Progress report slide deck summarizing WholeTraveler data and insight sharing across SMART Mobility Tasks in support of Work Flow	Slide deck submitted	3/31/2019	Quarterly	✓ SUBMITTED TO DOE
Determination of whether or not to undertake data collection in another region	Determination transmitted to DOE TM	3/31/2019	Quarterly	✓ DETERMINATION OF NO-GO FOR ADDITIONAL FY19 DATA COLLECTION TRANSMITTED TO DOE
Draft of 1-2 journal articles/reports	Reports submitted	6/30/2019	Quarterly	✓ SUBMITTED TO DOE (entries 2 & 6 in the table on next slide)
Draft of 2 journal articles/reports	Reports submitted	9/30/2019	Quarterly	✓ SUBMITTED TO DOE (entries 3 & 7 in the table next slide)

MILESTONES

	Description	Preliminary Analysis: starting	underway	complete	Writing up	Submission to DOE	Final revisions/ under review at publication	Published
1†	Describing the users: Understanding adoption of and interest in shared, electrified, and automated transportation in the San Francisco Bay Area					✓ Q3 FY2018 (Early)		Transportation Research Part D
2†	Children, Income, and the Impact of Home-Delivery on Household Shopping Trips					✓ Q3 FY2019 (On time)	Accepted for TRB and under review at TRR	**Revise and Resubmit at TRR**
3†	Life course as a contextual system to investigate the effects of life events, gender and generation on travel mode usage					✓ Q3 FY2019 (Early)	Accepted for TRB and under review at TRR	
4†	The WholeTraveler Transportation Behavior Survey: Decision-Making Data related to Transportation Energy Use in the San Francisco Bay Area					✓ Q1 FY2019 (On time)	Under review at journal Transportation	
5†	Children at home: how transitions through family stages relate to mobility patterns in the San Francisco Bay Area					✓ Q3 FY2018 (Early)	Being prepared for journal submission	
6†	Tensions and complementarities in mass transit and ride-hailing decisions through a survey-based randomization					✓ Q3 FY2019 (On time)	Accepted for TRB, being prepared for journal submission	
7*	Risk, Personality, Cost, or Household Tasks? Hypothesis Testing of Gender Differences in Plug-in Electric Vehicle Interest					✓ Q4 FY2019 (On time)	Accepted for TRB, being prepared for journal submission	
8*	Life course as a contextual system to investigate the effects of life events, gender and generation on long-term travel-related choices					Beyond number of deliverables promised		
9	Modeling Multimodality in the San Francisco Bay Area: How Human and Environmental Considerations Affect Transportation Behavior					Beyond number of deliverables promised		
10	No title yet: Variability and flexibility in short-term mode choice, route choice, travel time			(Delayed due to GPS data issues)		Beyond number of deliverables promised		
11	No title yet: Estimation of value of travel time			(Delayed due to GPS data issues)		Beyond number of deliverables promised		

† Summarized in 2019 DOE VTO AMR Presentation * Summarized in this presentation

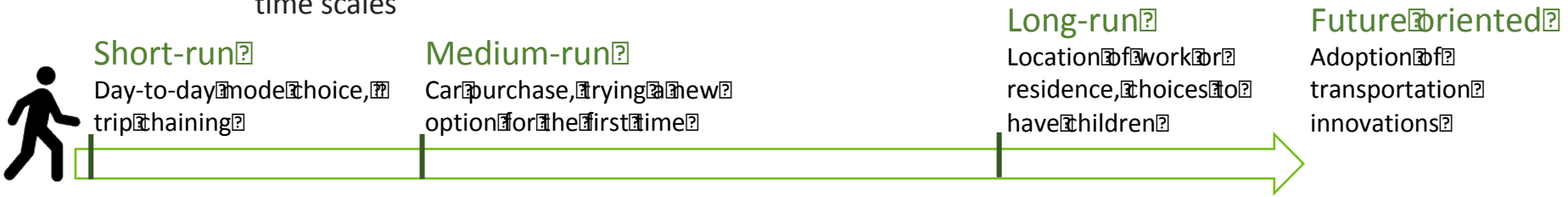
APPROACH

1. Survey-based data collection

- » Develop and integrate innovative survey methods (Phase 1 data collection) and low-cost, low-risk, low-hassle GPS data collection mechanisms (Phase 2 data collection)
- » Collect a rich array of information to study heterogeneous effects
- » Collect information regarding preferences across multiple technologies/services

2. Cutting-edge analytics

- » Analysis to gain insight into a number of pressing research questions
- » Integrated and dynamic assessment of drivers/barriers of transportation choices across multiple time scales



- » Focus on impact of:
  - Long-run lifecycle trajectory patterns;
  - Psychological and personality characteristics;
  - Risk and time preferences

APPROACH

Analyses

Use rigorous and innovative analysis approaches with the overall objective to uncover

- **travel choice patterns, preferences, and decision-making processes** with the **advent of new mobility technologies** multiple time-scales.

EV

Car-sharing

Connected and Automated Vehicles

Ride-hailing and shared mobility

E-Commerce

Focus on analyses that uncover how these patterns interrelate with **multiple dimensions of heterogeneity across the population** – characteristics that:

1. don't change over time (e.g., personality characteristics), or
2. change in predictable ways (e.g., lifecycle stage)

Provide insights and resources to **improve and accuracy and flexibility of transportation system simulation models and reduce uncertainty** associated with behavioral and human factors in transportation-as-a-system modeling and scenario analysis.

TECHNICAL ACCOMPLISHMENTS AND PROGRESS

1. Processing the Phase 2 Data to Create A Rich Resource for the Research Community

2. Gender Gaps in Vehicle Ownership and Spatial Mobility When Entering Parenthood: a Life Course Perspective

3. Risk, Personality, Cost, or Household Tasks? Hypothesis Testing of Gender Differences in Plug-in Electric Vehicle Interest

TECHNICAL ACCOMPLISHMENTS AND PROGRESS

1. PROCESSING THE PHASE 2 DATA TO CREATE A RICH RESOURCE FOR THE RESEARCH COMMUNITY

TECHNICAL ACCOMPLISHMENTS

Data Sharing

- **The de-identified Phase 1 dataset is currently shared with 21 SMART Mobility researchers**
  - Including researchers from: LBNL, ORNL, INL, ANL, NREL, and PNNL as well as academic collaborators working on SMART Mobility at a number of institutions
- **Pillars under which projects have been supported via WholeTraveler data access:**
  - Mobility Decision Science
  - Connected and Automated Vehicles
  - Workflow Task Force
  - Multimodal/Freight
  - Urban Science
- **Key thematic concentrations of interest**
  - E-commerce and shopping behavior
  - Adoption of emerging mobility technologies:
    - Automated vehicles (AVs)
    - Interest in electric vehicles (EVs)
  - General travel behavior in the context of current mobility options
- **De-identified version of the phase 2 GPS data prepared and shared with any interested SMART Mobility researchers**
  - Detailed GPS data; trip-level data (including defined trip chains); phase 2 questionnaire responses

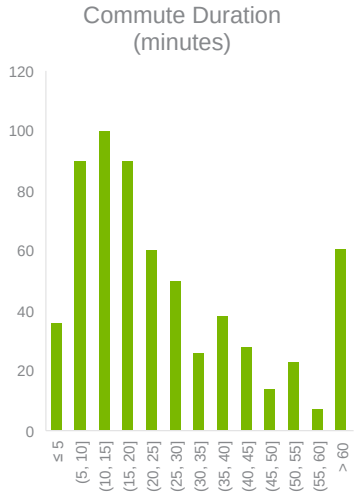
Anonymized versions of both the Phase 1 and Phase 2 data are in the process of being uploaded to the DOE-funded Livewire Platform to be made more widely available.

TECHNICAL ACCOMPLISHMENTS

Phase 2 Location Data

- **Larger than anticipating undertaking to clean the GPS data**
  - 288 Participants, 22 Unusable
  - Flag shared accounts
  - Adjust for accuracy issues
  - Identify drift
  - Process gaps in readings
  - Deal with different issues by phone type

- **Complicated process of defining "Trips" to which each GPS point is assigned:**
  - Started by leaving 250 meter zone
  - Ended by staying more than 10 minutes within 200 meter zone
  - Cross-checked with multiple approaches
- **Further challenging process of defining "chains" of trips**



Trip-end type based on Google lookups	Count
general street address	2643
Establishment	572
Bus station	227
Route	150
Food	116
Health	89
School	60
Doctor	60
General Contractor	57
Home Goods Store	57
Finance	50
Transit Station	48
Restaurant	47
Parking	42
Store	42
Cafe	42
Grocery or Supermarket	42
Lodging	40
Subway Station	35
ATM	32
Premise	30
Park	28
Department Store	26

TECHNICAL ACCOMPLISHMENTS

Phase 2 Location Data

- **The result of this effort:**
  - A fully cleaned and processed GPS location dataset including a rich amount of information (though anonymized by omitting the actual GPS coordinates and including only the census block group of each coordinate). This includes:
    - The type of location the point is at (e.g., home, primary destination, route, or other location types from Google Lookup)
    - The timestamp of each point
    - The distance between each point
    - The distance between each point and home and each point and primary destination.
    - A collection of trips to which each point are assigned with trip-level characteristics
    - A collection of trip chains to which each trip is assigned.
  - These data are linked to the phase 1 survey data by respondent ID
  - This dataset will be publicly available through Livewire to be a resource for researchers both within SMART Mobility and outside.

TECHNICAL ACCOMPLISHMENTS AND PROGRESS

2. GENDER GAPS IN VEHICLE OWNERSHIP AND SPATIAL MOBILITY WHEN ENTERING PARENTHOOD: A LIFE COURSE PERSPECTIVE

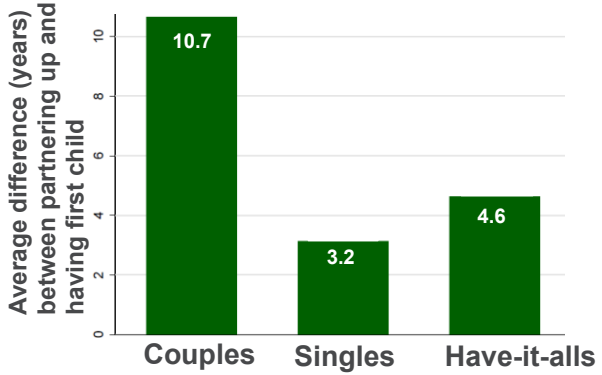
Authors: Ling Jin, Hung-Chia Yang, Alina Lazar, Annika Todd-Blick, Alex Sim, Kesheng Wu, C. Anna Spurlock

TECHNICAL ACCOMPLISHMENTS

Gender Gaps in Vehicle Ownership and Spatial Mobility When Entering Parenthood: A Life Course Perspective

- **Background**
  - Three prevalent life course patterns identified previously, all having similar school/career formation patterns early on.
  - Key differences in the timing of familial events.
- **Research Questions**
  - How does the timing of parenting affect short to long term mobility decisions: travel mode, vehicle ownership, and residential locations? And specifically, how do these effects differ by life course context?
  - Do men and women in these different life-course contexts respond differently?
  - What can these findings tell us about the nature of the gender gap and the underlying factors contributing to the transportation patterns we observe?

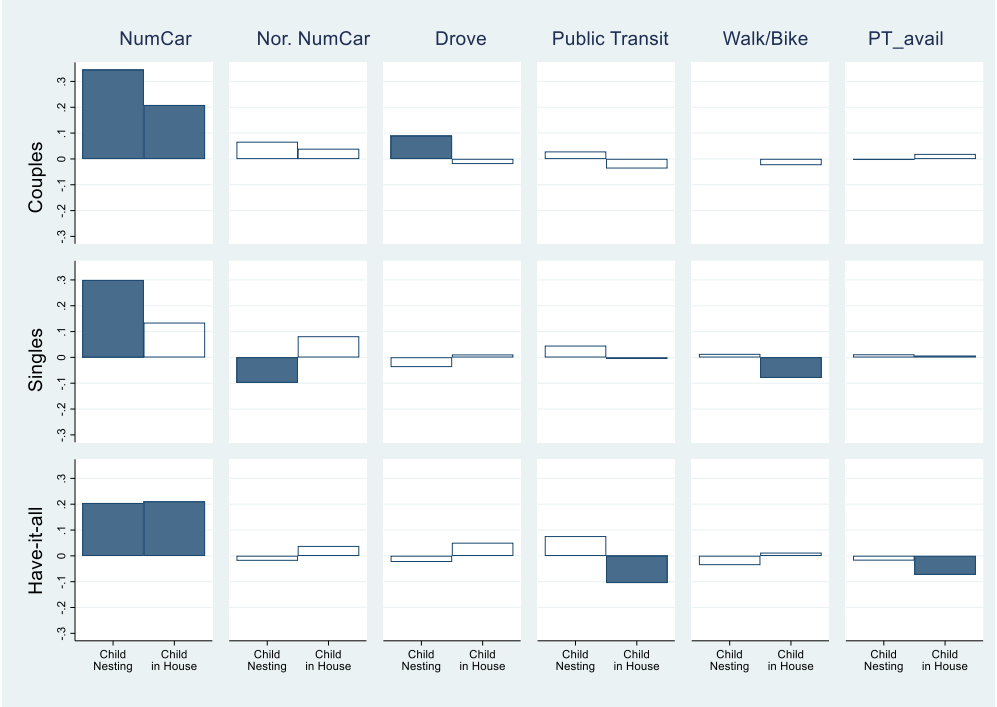
Singles: school/work early, delayed partner/children
Couples: school/work early, partner early, delayed children
Have-it-alls (HIAs): school/work early, couple/children slightly later



TECHNICAL ACCOMPLISHMENTS

Gender Gaps in Vehicle Ownership and Spatial Mobility When Entering Parenthood: A Life Course Perspective

Parenting effects: male baseline



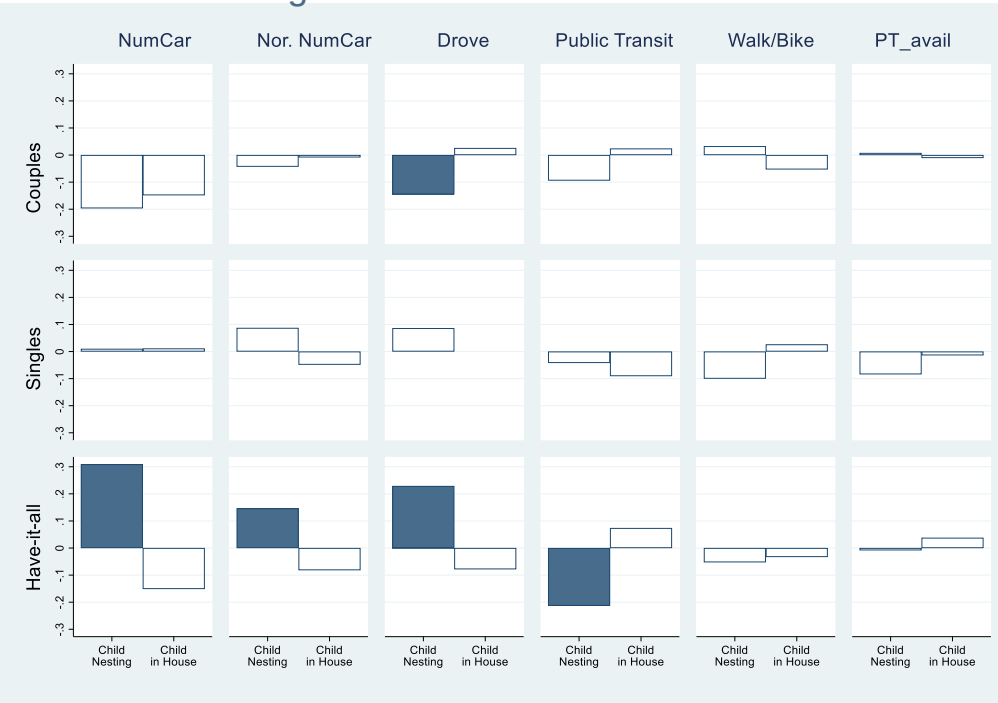
- **In the child nesting phase:**
  - Singles tend to reduce per-person car ownership.
  - Couples increase driving
- **Children in house phase:**
  - Have-it-alls increase likelihood of moving to a transit-poor areas and reduce use of public transit.
  - No significant change in per person car ownership
  - Singles reduce walk/bike

Note: bolded bars are statistically significant at 10% level.

TECHNICAL ACCOMPLISHMENTS

Gender Gaps in Vehicle Ownership and Spatial Mobility When Entering Parenthood: A Life Course Perspective

Parenting effects: female – male differences



- **Gender gaps between cohorts in numbers of vehicles owned, primary modes used, and whether public transit is available (PT_avail):**
  - Singles have minimal gender gaps
  - Have-it-alls have the most gender gaps in both car ownerships and mode uses.

- Also observed (not pictured):
  - **Gender gap in home location characteristics:** none identifiable.
  - **Gender gap in primary destination location/type characteristics:** HIA women are more likely to report that their primary destination is the school or workplace of a family member relative to HIA men.
  - **Gender gap in vehicle characteristics:** HIA and couples women are more likely to own SUVs relative to men in those cohorts.
  - **Gender gap in income:** HIA and couples women earn less relative to men in those cohorts.

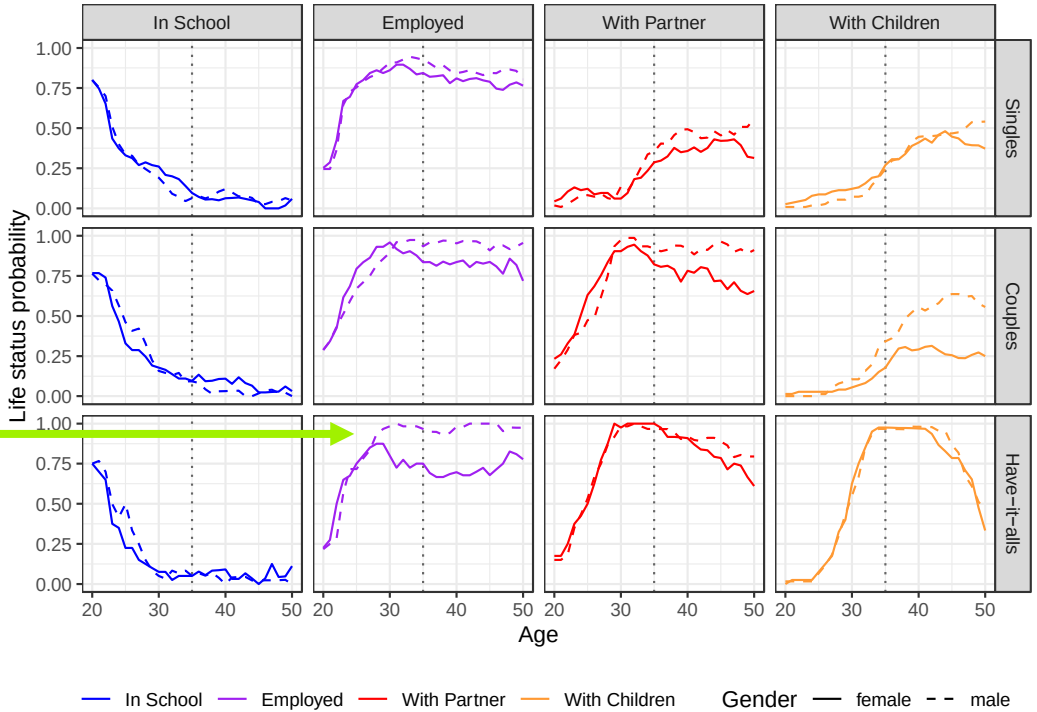
Note: bolded bars are statistically significant at 10% level.

TECHNICAL ACCOMPLISHMENTS

Gender Gaps in Vehicle Ownership and Spatial Mobility When Entering Parenthood: A Life Course Perspective

- Have-it-all Women's decision regarding continuing to work full time or not affects gender gaps in mid to long term mobility

Large full-time employment gap formed early on around time of family formation.



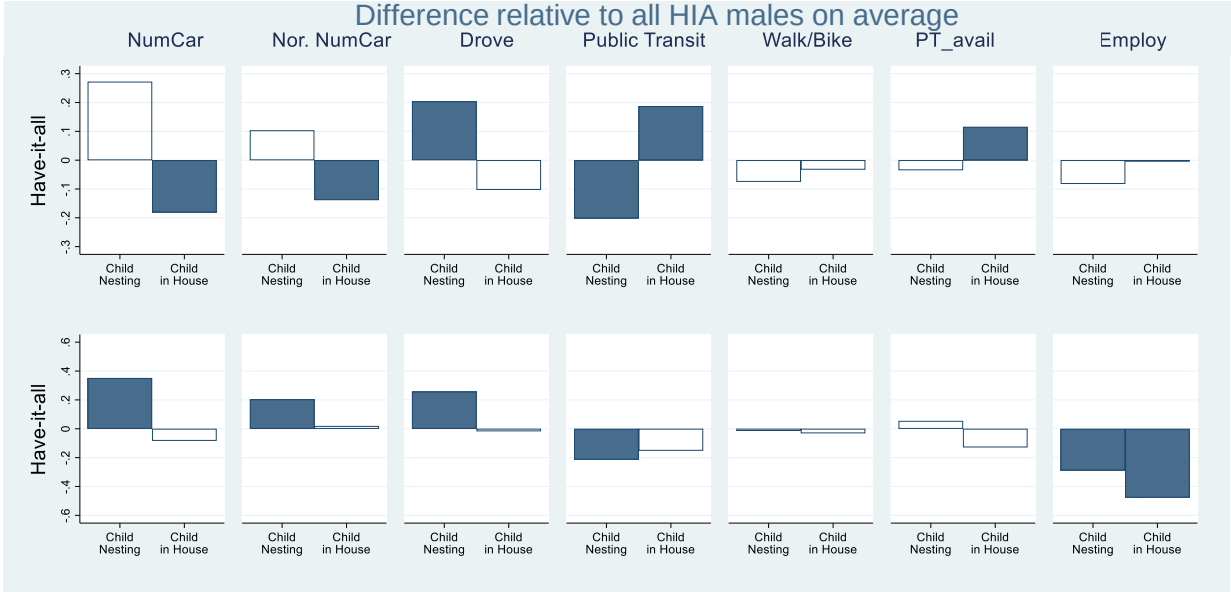
TECHNICAL ACCOMPLISHMENTS

Gender Gaps in Vehicle Ownership and Spatial Mobility When Entering Parenthood: A Life Course Perspective

- Have-it-all women take two career-related paths:
  - **Continuing to work full time while forming a family:** while increasing driving early on, they are more likely to reduce car ownership later on and move to a transit friendly area, and increase transit usage.
  - **Giving up working full time while forming a family:** increase car ownership and driving early on, and increased employment gaps later on. There is no difference in the availability of public transit where they live nor transit usage compared to males, indicating that these HIA women also move to a transit poor area.

Full time employed women during age 30-35 (65%)

Under-employed women during age 30-35 (35%)



Note: bolded bars are statistically significant at 10% level.

TECHNICAL ACCOMPLISHMENTS

Gender Gaps in Vehicle Ownership and Spatial Mobility When Entering Parenthood: A Life Course Perspective

- **What can these findings tell us about the nature of the gender gap and the underlying factors contributing to the transportation patterns we observe?**
  - **Takeaway**:
    - Women in the HIA cohort, relative to men in that cohort, experience significant career impact concurrent with family formation. HIA women, more than men, shoulder more family-member transportation responsibilities, reduce public transit use, live in households with more cars and rely on larger (SUV) vehicles.
    - HIA women, given this family context, take two paths:
      - Stay in the full time workforce (65%)
      - Leave the full time workforce (35%)
    - This is in contrast to HIA men, 98% of which (all but one respondent) stay working full time during family formation.
    - As a result, HIA women are more likely to earn less than HIA men on average.
    - Those that stay in the workforce are more likely, relative to men, to reduce car ownership, live in a more transit-rich environment, and increase public transit use.
    - Those that exit the full-time workforce tend to stay out in the long term, and remain in a car-dependent lifestyle.
  - This speaks to the flexibility in mobility choices these different paths tend to take.
  - There are open questions regarding family composition (do HIA men marry HIA women or vise versa?) that may shed more light on the family dynamics contributing to these different transportation behavior paths.

TECHNICAL ACCOMPLISHMENTS AND PROGRESS

3. RISK, PERSONALITY, COST, OR HOUSEHOLD TASKS? HYPOTHESIS TESTING OF GENDER DIFFERENCES IN PLUG-IN ELECTRIC VEHICLE INTEREST

Authors: K. Sydny Fujita, Hung-Chia Yang, Margaret Taylor, and C. Anna Spurlock

PUBLICATIONS AND PRESENTATIONS

Risk, Personality, Cost, or Household Tasks? Hypothesis Testing of Gender Differences in Plug-in Electric Vehicle Interest

- From initial analyses of the WholeTraveler Survey dataset (as well as other literature), we know that there are different rates of interest and adoption between genders for many types of emerging transportation technologies and services (in WholeTraveler respondents 63.5% of men and 48.8% of women express interest in owning a PEV in the future, a PEV gender gap of approximately 15%).

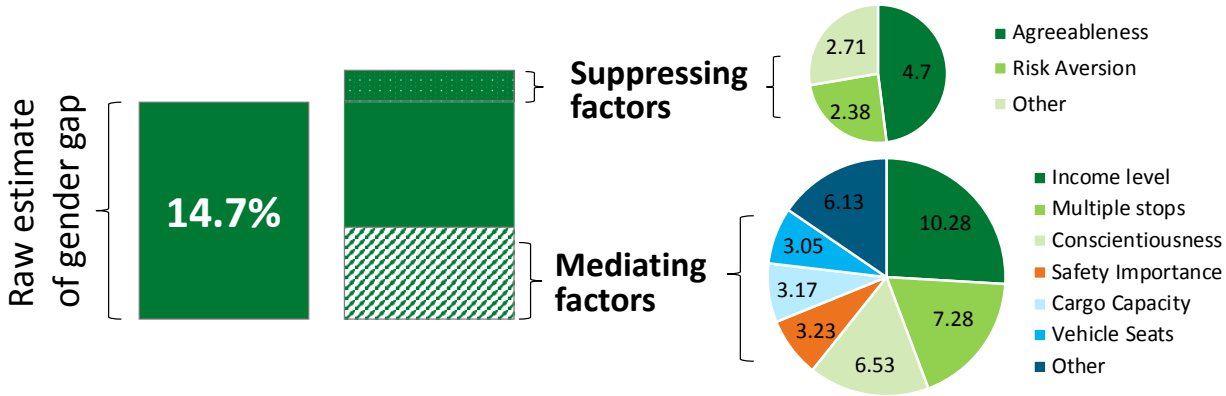
We use mediation analysis to explore a set of hypotheses aimed at addressing the question: **What underlying factors drive the observed difference in interest in PEV between men and women?**

Group	Hypothesis
H1: Risk	H1A: Monetary risk
	H1B: Certainty of timing
	H1C: Safety
H2: Personality	H2A: Openness
	H2B: Agreeableness
	H2C: Extraversion
	H2D: Neuroticism
	H2E: Conscientiousness
H3: Willingness and/or Ability to Pay	
H4: Transportation Preferences	H4A: Moving people and stuff
	H4B: Commute habits
H5: Environmental preferences	

PUBLICATIONS AND PRESENTATIONS

Risk, Personality, Cost, or Household Tasks? Hypothesis Testing of Gender Differences in Plug-in Electric Vehicle Interest

- Takeaways:
  - The variables included in the analysis mediate 35% of the gender gap, but also suppress 10% of the gender gap.
  - Two hypotheses account for the largest share of the gender gap in this analysis:
    1. factors associated with willingness or ability to pay (H3) taken together account for 10% of the gender gap
    2. factors related to household responsibility for transporting family members and household goods (H4a) account for 11% of the gender gap.
  - The largest single consistent mediator is income, with findings indicating that if women respondents had the same household income level as men respondents on average, the gender gap could be 10% smaller.
  - The largest single suppressor is agreeableness, indicating that if women had the same average rating on the agreeableness scale as men, the gender gap could be 5% larger.



RESPONSES TO PREVIOUS YEAR REVIEWER COMMENTS

RESPONSES TO REVIEWER COMMENTS

Some general responses provided here, more detail in backup slides:

- **Small response rate, self-selection bias, and unrepresentative sample:**
  - Response: These comments echo those that have been made in previous year.
  - We could not agree more.
  - We fully recognize the limitations of the data that were collected, and would wanted to do further data collection to expand to other regions.
  - With respect to the self-selected nature of the sample and the unrepresentativeness and how that might be problematic when results were integrated into other SMART projects, we would note that in critical cases where WholeTraveler results were used in other SMART Mobility analyses it was cases where no other data existed, so the choice would have been to use the WholeTraveler data, knowing it's imperfections, or make a complete blind guess.
- **The ambitious scope of work:**
  - Response: We agree that the scope was ambitious.
  - We ran into roadblocks with the phase 2 data that made the process of cleaning and pre-processing those data much more time-consuming than anticipated, we were able to add other analyses in that weren't originally planned.
  - We don't have as many papers submitted to journals yet as we would have wanted, but all deliverables promised to DOE were completed on time or early.
- **Importance of documentation and sharing of methodology and data products:**
  - Response: We wholeheartedly agree.
  - Detailed documentation of the survey design, data collection methodology, results of the data collection, pre-processing and data cleaning steps, survey instruments, and the anonymized data itself will all be made publicly available on Livewire.

COLLABORATIONS & REMAINING CHALLENGES AND BARRIERS

COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS

This project integrates with and supports the research of all pillars within the SMART Mobility Initiative:

- We have provided the fully dataset from the phase 1 data, are about to do the same for phase 2. As noted previously, these data are already being used by a number of researchers across SMART.
- We are also in communication with a number of other SMART Mobility tasks to coordinate our analysis in such a way that some of our output can be used in the models and simulations in the Workflow Task Force.

LBNL-lead Team

- **LBNL**
  - C. Anna Spurlock; PI; MDS Pillar Lead
  - Ling Jin
  - Annika Todd
  - Margaret Taylor
  - Saika Belal
  - John Wu
  - Alex Sim
  - Hung-Chia Yang
  - Sydny Fujita
- **NREL**
  - Andrew Duvall
  - Alana Wilson
  - Bingrong Sun
- **INL**
  - Victor Walker
  - Sawn Salsbury
  - Tessica Gardner
  - David Black
  - Mindy Gerdes
- **Academic Collaborators**
  - Gabrielle Wong-Parodi, Stanford
  - Emily Wells, CMU
  - Joan Walker, UCB
  - Menqiao Yu, UCB
  - Alina Lazar, YSU

Team members from across all three labs and our academic collaborators have coordinated in an integrated way on a number of parallel analyses and data cleaning/management efforts.

REMAINING CHALLENGES AND BARRIERS

- Project is at an end… no remaining challenges and barriers.

PROPOSED FUTURE RESEARCH

PROPOSED FUTURE RESEARCH

- In the technical back-up slides are described components of three projects proposed for SMART Mobility 2.0 that build off of work done in WholeTraveler.
- In these proposals a concerted effort is made to address important themes in valuable reviewer comments from these AMR presentation over the years including:
  - Broader representation (geographic, demographic, etc.) in and a less selected sample in cases where data collection are warranted.
  - A direct link between behavioral insights and energy implications with more of a careful connection to emerging technologies and services.
  - A more concerted focus on stakeholder engagement, tool development accessible to stakeholders, decision-makers, and policy designers, and more of a practical focus on application.
- The three proposals, elements of which are summarized:
  - MOTIVE (Mobility and Technology Insight Validation Evidence)
  - Workflow 2.0: new capabilities for the SMART Mobility Workflow BEAM implementation
  - Applying Workflow 2.0: To comprehensively understand key drivers of MEP, generate far-reaching insights, and deliver a reduced-form tool to transportation decision makers

"Any proposed future work is subject to change based on funding levels."

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WholeTraveler Transportation Behavior Study

FOR MORE INFORMATION

C. Anna Spurlock

Research Scientist

Energy Analysis and Environmental Impacts Division

Lawrence Berkeley National Laboratory

caspurlock@lbl.gov

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INL Idaho National Laboratory

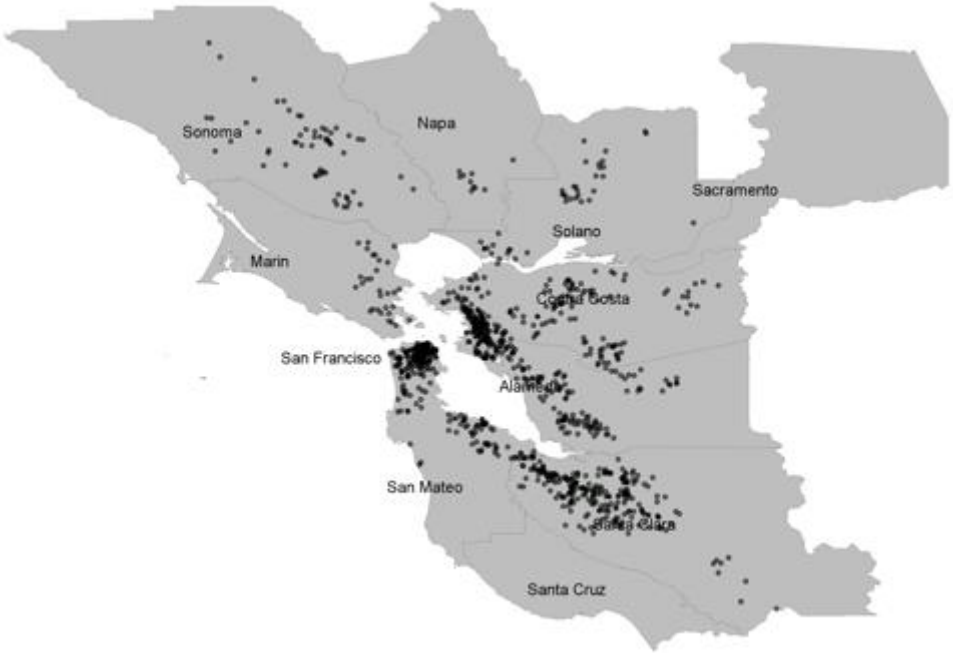
NREL

OAK RIDGE National Laboratory

TECHNICAL BACKUP SLIDES

APPROACH

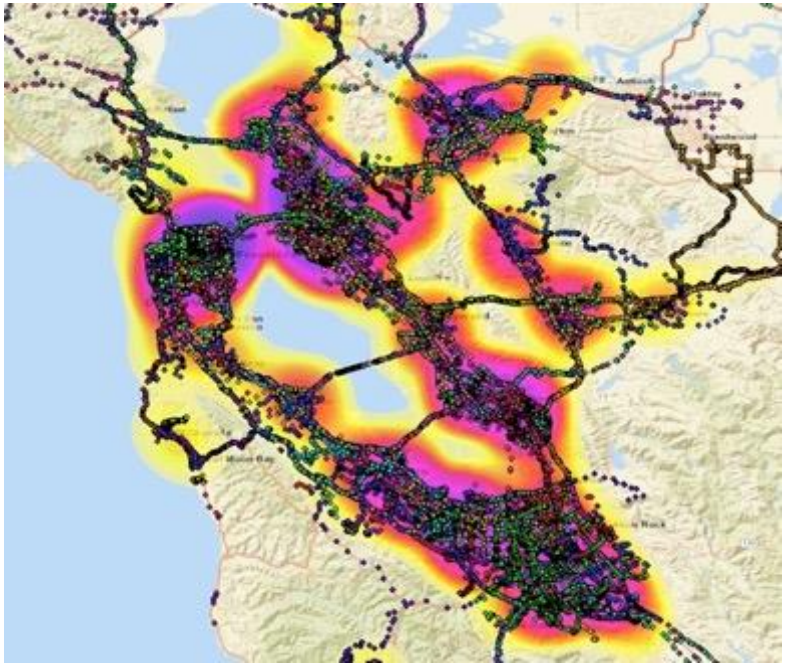
Phase 1 Survey



- Primary destination
- Mode use
- Preferences across mode characteristics
- E-commerce
  - Deliveries across different categories of goods
  - Trips replaced by these deliveries
  - Preferences for e-commerce
- Exposure to, awareness of, use of, adoption of, interest in different technologies and services
- Vehicle ownership
- TNC price sensitivity
- Personality/psychological characteristics
  - Big 5 Personality
  - Risk aversion
  - Discount rate
- Socio-demographics
- Life history calendar

APPROACH

Phase 2 GPS Data Collection



GPS Data

- One week of Google Location
  - Tracked by Google Maps
- Data attributes
  - Time-stamp
  - Lat/Long
  - Velocity
  - Altitude
  - Accuracy
  - Activity Prediction(*android only)

Phase 2 Questionnaire

- Modes used during the week
- Reason for choosing each type
- Primary purpose for each mode used.

Resolution

- Motion-based
- Approximately 3 minute interval when in motion
- Reveals general behavior and patterns versus momentary speeds and vehicle data.

GPS Analysis

- Number of daily trips
- Trip distance
- Commute time
- Average Speed
- Commute start/end
- Stops/trip chaining
- Ties to Public Transit
- Comparison to average commute time / Congestion
- Variability from day to day (Start time, location, route, trips, etc.)

DATA COLLECTION OUTCOMES

Two phase data collection completed in Spring of 2018

Phase 1

- 9 Bay Area counties
- Address-based random sample
- Mailed invitation + Reminder postcard
- Online only (laptop or desktop)
- English only
- $10 Amazon Gift Card

- **Results**
  - Data collected March - June 2018
  - 1,045 responses (1.7% response rate)
    EXCEEDED GOAL OF 900 RESPONSES
  - Median completion time 28 minutes
  - Higher educated and higher income than the general population

Phase 2

- Those that completed phase 1 could opt in to phase 2
- GPS data collection using Google Location History
- Data collected over 7 days
- $20 Amazon Gift Card

- **Results**
  - 301 submitted data
    EXCEEDED GOAL OF 200 RESPONSES

It should be noted that the resulting sample was relatively selected: higher income, better educated, and less diverse than the Bay Area population. All results from analysis of these data should be interpreted as representative of the respondent population, and not the population as a whole. Extension of the results to the broader population should be done with care and caveats.

TECHNICAL ACCOMPLISHMENTS

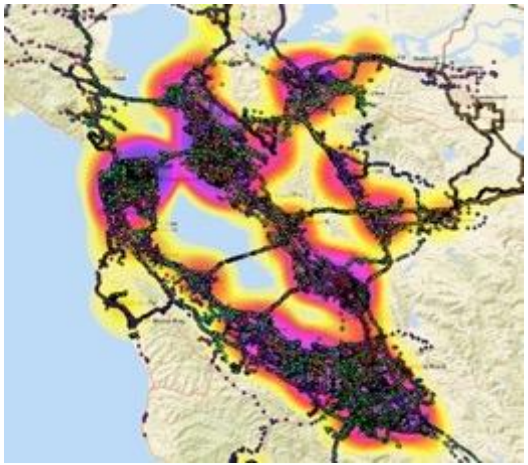
Phase 2 Location Data: Management and Cleaning

Collected Information

- **288 Participants**
- **22 Unusable**
- **March 15 – July 25, 2018**
- **~360,000 Recordings**
  - **1385 Average**
- **Average 308 seconds between readings**
  - **Android: 146 s**
  - **i-phone: 1,641 s**

Data Cleaning:

- Flag shared accounts
- Adjust for accuracy issues
- Identify drift
- Process gaps in readings
- Deal with different behaviors by phone type



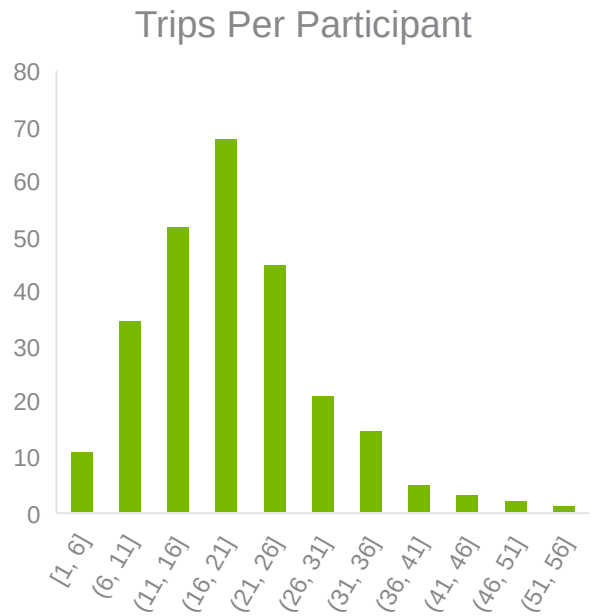
TECHNICAL ACCOMPLISHMENTS

Phase 2 Location Data: GPS locations translated to trips

Trips:

- **Started by leaving 250 meter zone**
- **Ended by staying more than 10 minutes within 200 meter zone**

(Also looked at trips based on ongoing motion)



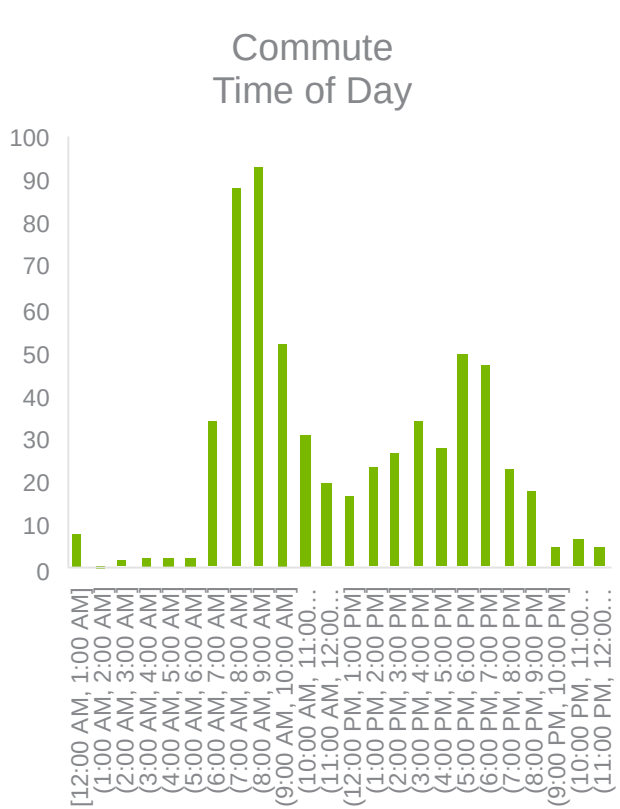
Trip-end type based on Google lookups	Count
general street address	2643
Establishment	572
Bus station	227
Route	150
Food	116
Health	89
School	60
Doctor	60
General Contractor	57
Home Goods Store	57
Finance	50
Transit Station	48
Restaurant	47
Parking	42
Store	42
Cafe	42
Grocery or Supermarket	42
Lodging	40
Subway Station	35
ATM	32
Premise	30
Park	28
Department Store	26

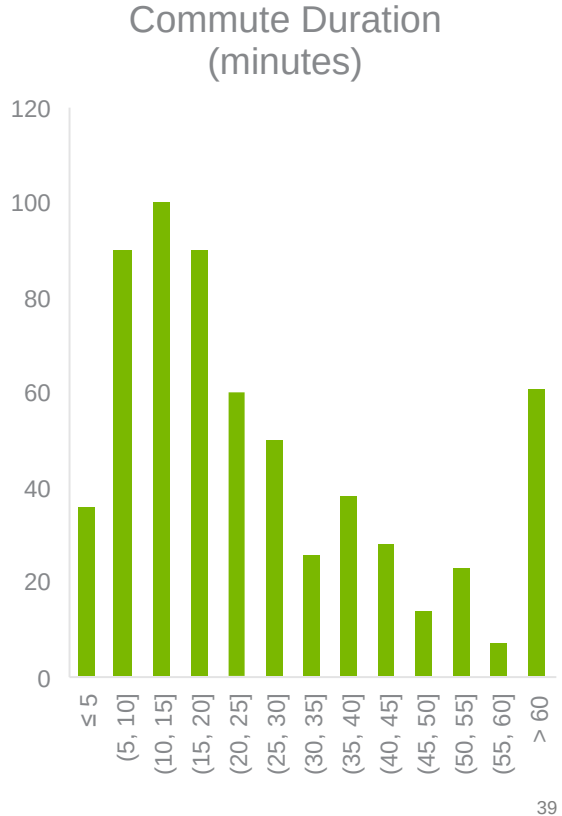
TECHNICAL ACCOMPLISHMENTS

Phase 2 Location Data: Commute trips focus on primary destination

Commute Trips:

- Trips starting or ending at home and primary destination
  - Not all commutes for work
- Chained commutes can combine trips into a full commute

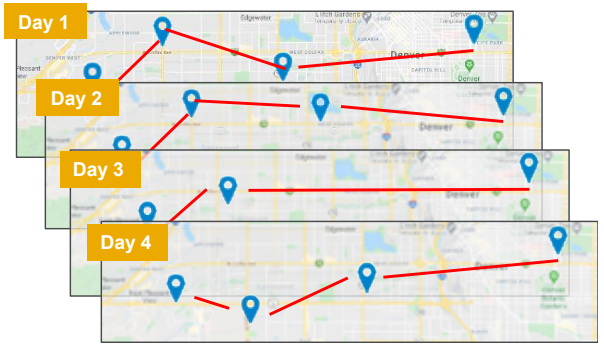




TECHNICAL ACCOMPLISHMENTS

Phase 2 data analyses Concept & Methodology : Travel pattern variability

- **Travel Pattern Variability**
  - Travel pattern: a sequence of travel activities (trips) described with multi-dimensional characteristics such as spatial and temporal information of origins and destinations, travel mode adopted for the trip
  - Variability: traveler's travel patterns vary across days and population groups



- **Methodology:**
  - Data: Whole Traveler Phase 2 data
  - Measurement: travel pattern variability score calculated based on trip temporal and spatial information
  - Analysis: merge Whole Traveler Phase 2 and Phase 1 data
    - Identify the common characteristics of travelers with comparable variability scores
    - Compare travel patterns of different population groups (e.g., commuters vs.. non-commuters; single modal users vs. multimodal users)

- **Expected outcomes:**
  - Understand different population groups' travel pattern flexibility
  - Identify population groups with highest potential to adjust travel patterns and potential energy benefits

PUBLICATIONS AND PRESENTATIONS

Risk, Personality, Cost, or Household Tasks? Hypothesis Testing of Gender Differences in Plug-in Electric Vehicle Interest

- Broadly, the mediation technique allows us to estimates the portion of the gender gap that is associated with differences in a mediating factor.
- There are two types of mediators:
  1. With a ***consistent mediator***, statistical adjustment for this third variable will reduce the magnitude of the relationship between the independent and the dependent variable.
  2. A ***suppressor or inconsistent mediator*** has the opposite impact; including a suppressing variable increases the magnitude of the relationship between the independent and the dependent variable.
- Mediation analysis is often applied in psychology and epidemiology, but applicable to consumer choice and environmental behaviors/preferences as well.

Our goal: estimate the ***indirect effect*** of variables, calculated by:

Indirect Effect: (1) **τ - τ '** or, (2) **αβ**, where:

$Y = \beta 1 + \tau X + \varepsilon 1$

$Y = \beta 2 + \tau' X + \beta z Z + \varepsilon 2$

$Z = \beta 3 + \alpha X + \varepsilon 3$

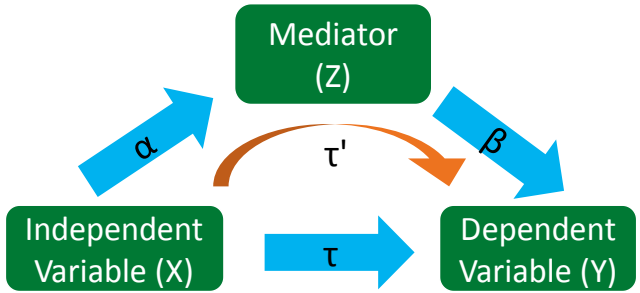
Y = dependent variable,

X = primary independent variable,

Z = mediating explanatory variable,

τ = Total effect, and

τ' = Direct effect.



PUBLICATIONS AND PRESENTATIONS

Risk, Personality, Cost, or Household Tasks? Hypothesis Testing of Gender Differences in Plug-in Electric Vehicle Interest

Group	Hypothesis	Key Variable(s)	% mediated (+) or suppressed (-)		
			By individual variable	By hypothesis sub-group	By hypothesis group
H1: Risk	H1A: Monetary risk	Risk averse identifier	- 2.38**	-3.80	-0.05
	H1B: Certainty of timing	Predictable time index Short travel time index	- 1.36** - 1.12**		
	H1C: Safety	Safety importance index Vehicle safety rating †	3.23** 0.41**†	4.98	
H2: Personality	H2A: Openness	Openness score	- 1.2**	-5.69	-0.40
	H2B: Agreeableness	Agreeableness score	- 4.71**		
	H2C: Extraversion	Extraversion score	- 0.39**		
	H2D: Neuroticism	Neuroticism score	0.81**	8.97	
	H2E: Conscientiousness	Conscientiousness score	6.53**		
H3: Willingness and/or Ability to Pay		Income level Low cost index Discount factor Predictable cost index Vehicle purchase price †	10.28** 0.74** 0.28** 1.66** 0.12**†	10.27	10.27
H4: Transportation Preferences	H4A: Moving people and stuff	Child(ren) in household Child transport index Vehicle seats (#) † Multiple stops index Low hassle index Vehicle cargo capacity †	0.28** 1.57** 3.17**† 7.28** 0.6** 3.05**†	10.17	9.99
	H4B: Commute habits	Primary commute distance‡	0.3**	0.3	
H5: Environmental preferences		Environmental index	-1.17**	-1.17	-1.17

Notes: (1) † denotes a vehicle-specific variable; for these variables, the sample size is reduced from about 900 to about 500 respondents. Any grouped result that includes this variable will necessarily operate off of the smaller sample size. (2) ‡ when reduced to the vehicle-specific sample, *primary commute distance* becomes a very weak suppressor, instead of mediator; we keep it separate in the first grouped column in order to provide an accurate assessment of H4A. (3) significance levels: ** denotes $p<0.05$.

RESPONSES TO REVIEWER COMMENTS

There were many comments from reviewers indicating the positive opinions:

- **General positive comments:**
  - the approach is good.
  - the scope of work is of very large magnitude, larger than initially envisioned, but is on schedule, with some products delivered early.
  - the project is well designed to be able to meet the technical barriers identified head-on. Specifically, the team has a clear understanding of the benefits and limitations of the survey-based approach, the conclusions that can be derived from such surveys, and other technical barriers, and that the results are still beneficial.
  - the project team is focusing on the right future technologies.
  - the project team has shown many more specific outcomes and a considerable amount of research output
  - the team has done considerable data sharing to other SMART research partners, a concrete collaboration that should yield benefits.
  - the PI has done an excellent job of uniting a very diverse group of project participants across the SMART Mobility Consortium.
  - the project team has provided a well-thought-out and extensive response to previous reviewer comments that shows its understanding of the datasets and to improving the future work plans.
  - this project supports the DOE objectives probably more so than the other projects because it is not a modeling exercise that is so academic but instead a fact-gathering exercise that could drive decision making efforts of cities that are faced with creating policy for new mobility.

- Response: The team would like to acknowledge these encouraging comments and would like to thank the reviewers for all of their thoughtful feedback and careful consideration of the work.

RESPONSES TO REVIEWER COMMENTS

There were many comments from reviewers indicating the positive opinions:

- **Confirmation of the values for certain areas of focus:**
  - Consideration of work regarding underserved communities is useful and such work is underrepresented in DOE analysis.
  - Understanding how lifestyle changes affect transportation is a key area. The impact of micro-mobility is a huge factor in transportation energy trends. The reviewer suggested that it is worthwhile investigating whether automated vehicle equipment will reach a price point where it becomes practical to make e-bikes and e-scooters into automated vehicles and what the consequences would be as automation could tame scooter chaos.
  - The reviewer noted that the effects of demographics on transportation choices has been undervalued in planning. It will be useful to characterize how much (if any) influence it has.
  - There are some interesting implications around the findings that online delivery of goods is supplementing but not necessarily replacing household shopping trips, and that this makes the DOE technology research about what vehicles deliver these goods even more important.
- Response: We agree with all of these points and hope to push things forward on these fronts in proposed SMART 2.0 work (summarized in the proposed future work slides in this presentation).

RESPONSES TO REVIEWER COMMENTS

Other comments and concerns expressed by reviewers collected by theme:

- **Small response rate, self-selection bias, and unrepresentative sample:**
  - The reviewers expressed concern about the small percentage of questionnaires returned as that indicates that **the sample is self-selected and biased**.
  - The team determined not to collect additional data from other cities, which was unfortunate. To be outstanding, the research would have required an **extension of this process to at least one other city** to be surveyed or a collaboration with another city to take the process and enact it under this project team's guidance.
  - Data sharing across SMART is good, but given the **unrepresentative** nature of the sample, could be problematic.
  - A key consideration for the project team that could help others replicate the results more successfully would be some ideas on **how future projects can limit the issue of survey self-selection**.
  - This project area could benefit from **additional resources** that would allow higher caliber and greater breadth of surveying to sufficiently build data sets.

- Response: These comments echo those that have been made in previous year. We could not agree more. We fully recognize the limitations of the data that were collected, and would wanted to do further data collection to expand to other regions. The primary constraint was not so much funding, as time (the process of implementing a collection such as this can be time-consuming involving a large number of review processes), and the priority was made to focus on generating results with the data collected rather than collecting additional data without time to analyze them, at least within the scope of this project period. With respect to the self-selected nature of the sample and the unrepresentativeness and how that might be problematic when results were integrated into other SMART projects, we would note that in critical cases where WholeTraveler results were used in other SMART Mobility analyses it was cases where no other data existed, so the choice would have been to use the WholeTraveler data, knowing it's imperfections, or make a complete blind guess.

RESPONSES TO REVIEWER COMMENTS

Other comments and concerns expressed by reviewers collected by theme:

- **The ambitious scope of work:**
  - Reviewers noted that the accomplishments and progress made are good; however, there are significant milestones and accomplishments that must be made in very short order to meet the project conclusion deadline in the fall of 2019, and that the scope planned seemed ambitious, if not overly so. One reviewer agreed with the no-go decision to not extend the survey to another geographic location, as it would have limited the ability to conduct in-depth analysis on the existing dataset and limit sharing of results, while another seemed to disagree, indicating that this project has a higher level of funding than most, but the scope at this point is quite large. Hence, the sufficiency of funding was unclear to the reviewer, especially given the "no-go" decision on additional data collection.

- Response: We agree that the scope was ambitious. We succeeded in meeting all promised deliverables and while we ran into roadblocks with the phase 2 data that made the process of cleaning and pre-processing those data much more time-consuming than anticipated, we were able to add other analyses in that weren't originally planned. We don't have as many papers submitted to journals yet as we would have wanted, but all deliverables promised to DOE were completed on time or early.

- **Documentation and sharing of methodology and data products:**
  - One reviewer expressed interest in seeing if this dataset were included in the data products for the LiveWire project under development. According to another reviewer, making sure that the process is clearly captured and learning is incorporated into a fully documented process for future use are critical elements that will cause this project to have the highest value, and that the documentation of the process must be a part of this future work.

- Response: We wholeheartedly agree. Detailed documentation of the survey design, data collection methodology, results of the data collection, pre-processing and data cleaning steps, survey instruments, and the anonymized data itself will all be made publicly available on Livewire.

RESPONSES TO REVIEWER COMMENTS

Other comments and concerns expressed by reviewers collected by theme:

- **Appropriateness of this work to be funded by DOE:**
  - There were some differing opinions between reviewers regarding the role of DOE in this type of research. On the one hand, one reviewer comments that marketing is likely to be a bigger force in the coming transportation revolution than technical merits, but suggested that investigators should consider the extent to which government marketing is appropriate. While another reviewer commented that a propaganda drive by the U.S. government was effective in reducing car ownership and encouraging car sharing during World War II, and that climate change may be an existential crisis that demands government intervention. It was noted that it will be critical for research to remain focused on energy relationship for any future research funded by DOE.
- Response: We agree that the WholeTraveler focus was not as directly focused on the energy outcomes as we would have liked. We have learned a huge amount from this body of work, however, and see exciting paths forward to make this link much more directly in proposed future work. The role of DOE, to our understanding, is not to market, promote, or design policy. The role of DOE is to provide results that other planners, stakeholders, and policymakers can use in their work, and to inform the technology goals and research investment objectives of DOE.
- **Appropriateness of methods to address EEMS goals:**
  - It was unclear to one reviewer whether the data or analysis methods are optimal to investigate the topics of most importance to EEMS. One of the early articles is about effects of children at home but does not purport to address how that may be changing with the advent of emerging mobility options, which is a key question for EEMS.
- Response: This is a valuable comment. We have tried to make the case, in many of our sets of results, that the underlying barriers and drivers of behaviors that we're finding have important implications for emerging technologies, but we haven't yet made the link in all cases as completely as would be ideal. We have exiting plans to do this explicitly in the proposed work for SMART 2.0.

RESPONSES TO REVIEWER COMMENTS

Other comments and concerns expressed by reviewers collected by theme:

- **Nature of collaboration and greater application and interaction with stakeholders on the ground:**
  - The level of collaboration among the laboratories is high (e.g., judging from joint articles), but collaboration with the academic community is less clear. For projects in the EEMS program to be truly successful, the future research proposed must address plans to obtain feedback from real-world implementers of relevant mobility systems and then get the insights gathered by the research into the hands of implementers. To be outstanding, there needed to be more comprehensive collaborations with local stakeholders, i.e., government agencies. Proposed future research lacks real-world implementation connection.
- Response: University researchers were involved in the survey design, and in some of the analyses that ended up more delayed, so those results haven't been as thoroughly presented here, but there are results emerging in those cases. We agree that we haven't been as focused on real-world and stakeholder connection. In proposed future work summarized in this presentation we hope to build off of WholeTraveler, but rectify this shortcoming.

"Any proposed future work is subject to change based on funding levels."

PROPOSED FUTURE RESEARCH

MOTIVE (Mobility and Technology Insight Validation Evidence)

- Builds off of what was most valuable about WholeTraveler, while narrowing the focus to data needed to support SMART Mobility modeling and Workflow efforts most directly.
- Will prioritize a sample that is as representative as possible, including a range of geographic areas, and emphasis on underrepresented groups, and a multi-media survey implementation strategy to maximize response rate.
- Will address data needs of the modeling work funded under SMART 2.0
- Will focus on, among other things, some key gaps of data still needed:
  - **Value of travel time:** generate estimates that vary across individuals and over time using an experimental design to disentangle VOTT from travel choices, and link it to key underlying individual and trip characteristics.
  - **Vehicle ownership/technology adoption**: More data is necessary to establish proper linkages between household characteristics and dynamic lifecycle phases, mode take-up and use, vehicle ownership choices, technology adoption, and residence location in the Workflow.
  - **E-commerce consumer data:** Remaining questions include, for example: how sensitive is e-commerce usage to factors such as cost, convenience, delivery time or other characteristics of the service likely to be affected by alternative technology and service offerings and scenarios? In addition, in the current context with COVID-19 disrupting the economy, travel, and e-commerce behaviors, it is critical to collect information capturing how these disruptions have played out and how permanent they are.

"Any proposed future work is subject to change based on funding levels."

PROPOSED FUTURE RESEARCH

Workflow 2.0: new capabilities for the SMART Mobility Workflow BEAM implementation

- Three tasks within this proposed work build directly off of the innovative insights gained from WholeTraveler on lifecycle patterns and implications for modeling behavior and resulting energy outcomes.
  - **Demographic Evolution:** A comprehensive population evolution model for forecasting the socioeconomic and demographic characteristics of the population, with disaggregated spatial location, will be developed for integration into UrbanSim. The population evolution model will comprise a number of structural models mimicking various individual and household level characteristics and life cycle events into the socio-economic and demographic forecasting process.
  - **ATLAS (Automobile and Technology Lifecycle-based ASsignment) Household Vehicle Transaction Model:** The household vehicle transaction model integrated into the workflow will be enhanced to reflect the best available knowledge from the literature and insights from the WholeTraveler Transportation Behavior Study, will be supported and further developed by new data collected in the MOTIVE, and will accommodate the relevant dimensions of heterogeneity enabled by the demographic evolution task. The objective is a vehicle transaction model capable of capturing dynamics in lifecycle evolution coupled with technology choice.
  - **Improved mode choice modeling in the Workflow:** As utility functions of agents are refined in UrbanSim and via ATLAS to account for heterogeneous preferences for longer term choices, similar improvements to mode choice will be implemented to align with this type of heterogeneity. Using data from MOTIVE, this task will assess approaches for revising the mode choice models, implement the improvements, and validate those changes. Leveraging work funded by EEMS under NREL's 1629 FOA project with UC Riverside, one approach for improving the mode choice model is using "Fundamental Influencing Factors," through which preferences for modes are specified based on the primary underlying characteristics of the modes, and rely less on mode-specific constants in calibration.

"Any proposed future work is subject to change based on funding levels."

PROPOSED FUTURE RESEARCH

Applying Workflow 2.0: To comprehensively understand key drivers of MEP, generate far-reaching insights, and deliver a reduced-form tool to transportation decision makers

- Proposed for SMART Mobility 2.0
- More deeply and directly links behavioral results from WholeTraveler and follow-on related work to system level energy outcomes using the Workflow.
- The primary objective of this work is to amplify the value of insights generated from the Workflow beyond the initial limited set of scenarios simulated in SMART 1.0 and develop an insight driven exploratory tool for use by transportation decision makers. This will be achieved by deriving a comprehensive understanding of the sensitivity of Workflow outcomes to the full array of parameters and assumptions built into the models, and by conducting innovative analyses of those outcomes and their sensitivity to extract insights that are only identifiable using the full potential of a comprehensive modeling environment like the SMART Mobility Workflow. In all cases, impacts of emerging technologies and services will be assessed, innovative metrics such as MEP and its extensions will be used, and implications for the VTO research portfolio will be articulated.
- Derive specific thematic insights: There are thematic categories of insights that can only be explored using a comprehensive model environment like the Workflow: (1) system-level feedback loops limiting extreme outcomes, (2) spillover effects and distributional effects, (3) tipping points and non-linear effects, and (4) the interrelationship between land-use, network structure, and behavioral factors.

"Any proposed future work is subject to change based on funding levels."